Review on Development of Mechanisms for Shoulder-Launched Missile Technology.

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Abstract - The creation of a damping mechanism for shoulder-launched missiles is crucial for mitigating recoil, ensuring operator safety, and boosting accuracy during firing. Launching these weapons exposes users to substantial force and vibrations, which can lead to fatigue, injuries, and lower performance levels. This project aims to design a comprehensive damping system—be it mechanical (spring-damper), hydraulic, or hybrid—that effectively absorbs and dissipates recoil energy. We will investigate missile thrust dynamics, user ergonomics, and energy transfer characteristics to develop a compact and efficient recoil mitigation solution. By conducting simulations, selecting appropriate materials, and testing prototypes, we intend to guarantee the mechanism's structural integrity and reliability in combat situations, while also prioritizing user comfort without sacrificing weapon performance. This innovation promises to greatly enhance portable missile systems by improving safety, reducing training requirements, and maximizing operational efficiency on the battlefield.

Key Words: recoil, mechanism, vibrations, energy, missile, safety, mitigation, efficiency, ergonomics.

1.INTRODUCTION

Shoulder-launched missile systems, or man-portable air-defence systems (MANPADS) or man-portable anti-tank guided missiles (MPATGMs), are used extensively in contemporary warfare because they are mobile, effective, and simple to operate by a single soldier. The missile systems are of the essence in ground fighting situations where speed deployment and high agility are necessary. Nevertheless, even with their benefits, they have a serious disadvantage—**the excessive recoil force and vibration imparted at the point of firing**. This abrupt rearward force, caused by the ejection of the missile at high speed, can be physically challenging to the operator, leading to discomfort, fatigue, without a recoil damping mechanism, operators have to endure most of this force against their shoulder and body, which becomes especially troublesome in repeated firing or high-stress combat situations. Furthermore, free vibrations during missile launch can cause unstable weapon attitude, impact trajectory accuracy, and raises the risk of mission failure. With the modern battlefield ever more requiring speed, precision, and less operator fatigue, there is a definite need to resolve the issue of recoil control in such weapon systems.

This project aims at **designing and implementing a successful damping mechanism** that can be integrated into shoulder-fired missile systems to mitigate recoil force and vibration transmission. By incorporating a compact damping system—mechanical, hydraulic, or hybrid—the effect on the operator can be meaningfully alleviated, resulting in better weapon control, firing accuracy, and operator safety overall. The design should satisfy demanding constraints of weight, dimensions, ruggedness, and reliability without compromising the performance of the missile.

The design process starts with a study of the physical and dynamic properties of the missile, i.e., mass, thrust force, impulse duration, and operator biomechanics. These quantities are used to estimate the recoil force and to model the way that the energy is passed through the system. Multiple damping concepts will be considered, including spring-damper configurations, fluid-type dampers, and composite material buffers. Computational software such as SolidWorks for CAD design modelling and ANSYS or MATLAB for simulation and dynamic analysis will be utilized to analyses and optimize the design.

2. Literature Review:

Siniša Jovančić, Danica SimićAcademia, "Design of Shoulder-Launched Unguided Rocket with Thermobaric Warhead"

This paper outlines a methodology for calculating the geometrical and mass parameters of a shoulder-launched rocket equipped with a thermobaric warhead. The design of the rocket is optimized to meet specific tactical and technical requirements, focusing on mass efficiency through two calculation methods.

The first method determines the rocket's Caliber based on the payload mass for a given maximum range. The second method predicts the Caliber value, allowing for the calculation of the masses of all rocket sub-assemblies and thus the total mass of the rocket. Notably, the optimal Caliber for a rocket motor with limited operating time emerges as a consistent solution across both iterative processes.

In a specific example presented, the model is applied to defined tactical and technical requirements along with known material characteristics. The parameters for the warhead and rocket motor are calculated and analysed accordingly. For the chosen design parameters, simulations are conducted to evaluate the motor's operating time and the rocket's trajectory within its launching tube at three standard environmental temperatures: -30 ºC, +20 ºC, and +50 ºC. The resulting values for chamber pressure, motor operating time, and initial rocket velocity are examined, ensuring the safety of the shooter while achieving the desired ballistic characteristics. [1].

Qinghua Ma; Haiqing Li, ‘‘Design of Attitude Control Law for Over-Shoulder Launch of Helicopter-borne Air-to-ground Missile”

This paper achieve a successful agile transition for the over-shoulder launch of helicopter air-to-ground missiles we propose a design method for an attitude controller utilizing a sliding mode approach the missiles motion equation is formulated using quaternions we then apply a small disturbance linear state space model to guide the control system design by leveraging a linear distribution strategy for the Airgas-rudder composite actuator we derive a simplified model for the control system the attitude controller is constructed based on sliding mode theory incorporating disturbance compensation to ensure system stability simulation results confirm the effectiveness of the quaternion-based motion equation demonstrating that the attitude control system can accurately track pitch attitude commands and fulfil performance expectations [2].

Tao Li, Huafang Chen, “The Development of the Combined Weapon of Light and High Manoeuvring Artillery from the View of the Warfare Object’’

The paper with the shift in air-raid operation modes and the emergence of new threats along with the pressing need to protect critical ground defence targets from air attacks and missile threats the focus of air-defence systems has significantly evolved consequently various technical specifications and developmental pathways for air-defence equipment are also adapting one notable innovation is the light-duty high-manoeuvring system recognized for its numerous advantages including a high muzzle velocity rapid firing capabilities and the ability to create a dense projectile curtain this paper assesses the essential targets for light-duty high-manoeuvring artillery when integrated with other weapon systems detailing their defensive capabilities and offensive characteristics it also outlines the trajectory for the development of missile-artillery hybrid systems offering valuable insights for relevant organizations [3].

Mostafa Khalil, “A Preliminary Multidisciplinary Design Procedure for Tactical Missiles’’

The objective of this paper is to create a preliminary design process for an unguided tactical missile that employs a single-stage solid propellant motor, intended to deliver a specified payload over a targeted ground range. Drawing on data from similar mature missile systems, we established two empirical formulas to assist in the initial sizing of the missile, taking into account the slenderness ratio, warhead weight, and the desired range on the ground. We explored two different design concepts focusing on tubular and star grains that utilize various propellant compositions and chamber filling coefficients, all while adopting a body-alone airframe configuration. The findings affirm the effectiveness of the proposed design methodology in establishing the detailed design parameters. Additionally, we examined how variations in propellant compositions and chamber filling coefficients influence the achieved ground range [4].

T. Mohan Reddy, “Design and development of Propulsion System for Antitank Guided Missile”

A propulsion system has been conceived and crafted specifically for the third-generation anti-tank guided missile (ATGM). This innovative design features a distinct booster paired with a sustainer, where the booster is positioned in front and is equipped with four nozzles angled towards the missile's axis. The sustainer expels gases through a supersonic blast tube.

The development of the propulsion system's low-smoke, high-energy nitramine propellant was successfully undertaken by the High Energy Materials Research Laboratory (HEMRL) in Pune, with flight tests yielding positive results. The booster utilizes a tube-in-tube grain configuration with end inhibition, while the sustainer is designed with an end-burning configuration. To ensure optimal performance, high-strength aluminium alloy HE-15 has been employed for the construction of rocket motor components. Thermal protection is provided by a glass-phenolic composite ablative material, and high-density graphite is utilized in the nozzle throats.

This document also outlines the design considerations and methodologies relevant to grain configuration, nozzles, and igniters. Extensive static and flight tests have been conducted, confirming the propulsion system's reliable performance [5].

Chhavi Chhavi, Vikram Ramanan, ‘‘ Modelling and Theoretical Design of Missile Launch System Utilizing Electromagnetism’’

The current study sets out to theoretically design and fine-tune an innovative propulsion system based on electromagnetism. This system is intended to launch missiles at high speeds before secondary propulsion methods, such as ramjets or scramjets, become operational. The design takes into account a range of theoretical and optimization aspects, including assembly geometry, materials, structural integrity, propulsion mechanics, and necessary power resources.

In this design, the missile is housed within a pod, and the missile-pod unit is propelled through a series of coils, functioning similarly to a coil gun. The entire system is based on the assumption that the propelled materials are ferromagnetic. Key design constraints focus on achieving a final velocity comparable to that of an intercontinental ballistic missile during cruise. We estimate the time needed to accelerate the projectile by analysing the maximum structural loads it must endure—namely tension, bending, and shear—and applying relevant failure criteria.

To mitigate aerodynamic drag and enhance inductive coupling, the missile accelerates within an evacuated annulus. We employ Maxwell's laws of electromagnetism, along with certain constraints and missile geometry, to determine propulsion and design parameters. The optimization process includes variables such as the radius of the evacuated annulus, current strength in the primary coil, the number of turns in each coil, and the total coil count. Material selection for the coil aims to balance thickness and Joule heating while considering cooling system requirements.

Additionally, we address the actuation mechanisms needed for three-axis control of the missile and annulus assembly, which is crucial for achieving the desired trajectory. This includes estimating the valve operation time to prevent shock formation within the annulus. We also evaluate the power requirements for this design, further establishing the novelty of our end-to-end solution for a theoretical propulsion system.

Finally, we compare this cutting-edge design with traditional chemical propulsion methods for similar missile classes, assessing both economic savings and carbon footprint reductions. Our proposed design is not only feasible with existing resources but also sustainable, avoiding long-term challenges associated with chemical propulsion, such as storage degradation and replenishment issues [6].

Berko Zecevic, “Specific Design Features of Solid Propellant Rocket Motors for Shoulder-Launched Weapon Systems’’

In this paper Solid propellant rocket motors designed for Shoulder Launched Infantry Weapon Systems (SLWS) are known for their brief burn times and high-pressure combustion, alongside a variety of structural design options. The interior ballistic behaviour of these motors is influenced by numerous factors, including design composition, propellant grain shape, the connection of the propellant grain to the motor case, the type and positioning of the igniter, spinning mode, and nozzle design. Additionally, erosive burning is significant due to the high mass flow rate of the combustion gases.

This paper presents a numerical simulation of the flow of igniter combustion gases through the hollow propellant grain tubes, including an analysis of gas temperature distribution. The findings support the hypothesis that the flow of gases from the igniter significantly impacts the duration of the pressure rise. A mathematical model was proposed to predict the relationship of pressure over time, represented as $p = f(t)$, integrated into a refined propellant grain burning surface model for two short-time rocket motor types. The results showed a commendable alignment with the measured curves [7].

Thurpunati K areem Basha, “Optimization of Missile Control System under Dynamic Loading of Two Materials Namely Aluminium 24345 and S2 Glass’’

In this paper, we explore the effectiveness of missile control bays as one of the most reliable methods for directing missiles towards their targets. They are capable of generating the necessary propulsion through direct actions around the centre of gravity. The design and power requirements of control surfaces significantly influence these aerodynamically controlled systems. Unfortunately, during launch, missile control components are subjected to high random vibration loads from other equipment, which can be detrimental. Therefore, mitigating these vibrations is crucial. It's essential to establish design specifications for missile control components that avoid common frequencies in order to prevent damage and failure caused by dynamic coupling [8].

H. Kentagens, "Anti Structure Shoulder Launched System – Insensitive Munition Program"

The Anti Structure (AS) shoulder launched system is a collaborative initiative between RAFAEL and Dynamite Nobel Defence. This innovative launcher employs the "Davis-Gun" principle, which utilizes a counter mass to achieve recoilless operation during launch. The AS projectile features a solid rocket sustainer motor, ensuring consistent velocity throughout its flight path by compensating for drag. It incorporates a tandem anti-structure dual mode warhead, allowing effective engagement of various urban targets.

From the outset, the design team prioritized an Insensitive Munitions (IM) compliant solution to meet customer needs, incorporating IM strategies into the development process. A thorough and progressive IM program guided the design and development phases.

Notably, a type I reaction was observed during a 2500 m/sec fragment attack on the BIC's booster in an unpacked state. However, recognizing IM considerations early in the design process facilitated the inclusion of essential features like advanced cure-cast explosives and a liquid counter mass. This proactive focus on IM requirements paved the way for a clear roadmap toward compliance.

Analysing the results through a comprehensive "full body of evidence" approach enhances our understanding and confidence in the system's insensitivity. Furthermore, packaging plays a crucial role in fulfilling IM requirements, serving both as a fragment blast shield and an insulator. It's essential to evaluate both packaged and unpackaged configurations at the Threat Hazard Assessment (THA) stage. Today, the AS stands as a qualified weapon system in active service [9].

Martin William Greenwood, "Apparatus and System to Counter Drones Using a Shoulder-Launched Aerodynamically Guided Missile"

The paper focuses on a new weapon system designed for the battlefield is being put forward to address the challenges posed by small drones. At its core is an aerodynamically guided missile that works seamlessly with existing multipurpose shoulder-launched weaponry. This system is highly portable, making it suitable for deployment among infantry units.

The findings of this paper highlight that the proposed guided missile system presents a viable solution to the growing threat of small drones in military operations. As the use of drones becomes more widespread in combat, it's essential to have innovative countermeasures in place to safeguard ground troops [10].

Matthew J. Sanford, "Energy Absorbing Counter mass for Shoulder-Launched Rocket Weapon''

This paper details the design of an innovative energy-absorbing counter mass specifically for shoulder-launched rockets. The counter mass is strategically positioned behind the rocket round within the launch tube, enabling the rocket's exhaust blast to be sufficiently modified. This allows for the safe operation of a rocket weapon from within a bunker or similar structure.

The counter mass comprises a central cylindrical section crafted from a crushable aluminum honeycomb material. At the front end of this section, a lightweight piston is affixed, while a mass mechanism is connected at the rear. This mass mechanism consists of a cylindrical enclosure with opening leaves, housing an envelope filled with frangible material.

Upon firing the rocket round, the piston compresses the crushable material, and once the compression stroke is complete, it triggers the release of the frangible mass. This innovative approach ensures that the exhaust blast is effectively managed, paving the way for the use of the rocket weapon in confined spaces like bunkers or other structures [11].

CONCLUSIONS

During literature review it is found that very few literatures are available on shoulder launched missile technology. No one had done any work related to development of mechanism and analysis and material selection for damping mechanism for shoulder launched missile technology. In this research work same is done. This work will be going to help for designing the damping mechanism for shoulder launched missile technology.

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